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RESEARCH INTO INTELLECTIVE LOAD CARRYING CAPACITY

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CHAPTER I

INTRODUCTION

A considerable emphasis has been placed, over the years, on description and evaluation of the sensory and motor aspects of the performance of the human component in a man-machine system. Data relating to man's ability to detect and discriminate auditory, visual, and tactile stimuli, his reaction time to diverse forms of stimulation, and the power and precision with which he may set or manipulate various controls, etc., are available and are routinely applied during early stages of system design.

In contrast, there is a remarkable absence of corresponding data concerning the mental or intellective components of a system operator's tasks. No guidelines are now available which indicate how quickly or accurately an operator may perform mental functions of varying types and difficulty levels. Furthermore, the need for information of this type is growing. As more and more of the relatively routine or determinable tasks performed by the operator become automated, there is an increased emphasis on the decisions and evaluations performed by the operator.

The present program was undertaken as a step towards the development of a method for measuring the intellective load carrying capacity of system operators. Such information possesses implications for behavioral description/evaluation and the consequent derivation of "human engineering guidelines" for mental tasks similar to those now available for perceptual and motor skills.

The basic structure for the present program rests on a logic described by Siegel and Cosentino (1971). The logic involves varying the intellective load on a operator in a controlled, quantifiable manner, while he performs a perceptual-motor task of constant difficulty. The point at which the human transfer function, for the perceptual motor task, suffers degradation is said to be the intellective load carrying threshold. Specifically, the Siegel and Cosentino technique is said to provide answers to such questions as:

- At what intellective load level does an operator's motor performance start to deteriorate?
- What is the effect of various types of intellective load on an operator's performance?
- Can an operator manage a higher load for one type of intellective task than for a second type of intellective task?
- What type of information presented to the operator causes the earliest overload?
- Does presenting the same information, in a different manner, produce a different intellective load on the operator?

Purpose of Current Program Phase

The goal of the first phase of the current program is to construct the hardware system necessary for conduct of research directed toward the goals discussed in the previous section. The design of this system was described by Siegel and Cosentino (1971). Certain modifications have since been made to the system and considerable progress has been made toward its actualization.

Background Logic

The logic of intellective load carrying measurement technique calls for the presentation of stimuli in such a manner that the intellective load on the experimental subject is systematically increased while the perceptual-motor load is held constant. Measurement and analysis of perceptual-motor response (human transfer function) will permit estimation of the intellective load threshold of an individual subject by determining the point in the difficulty of the intellective stimuli at which psychomotor performance is caused to deteriorate. This point will be considered indicative of the individual's intellective load carrying threshold for a specific type of mental function.

Intellective Load

As the result of a research program conducted over the years, Guilford and his associates (1950, 1954, 1964, 1966, 1967) have developed a three-factor taxonomy of human mental operations. Based on factor analytic procedures, 120 non-overlapping intellective activities have been described. The three factors employed by Guilford include: (1) "contents," indicative of the form in which information may be presented to the human, (2) "operations," describing the types of processing applied to the information by the human, and (3) "products," which describe the forms in which the output of the operation may occur. Within contents, four categories exist: figural, symbolic, semantic, and behavioral. Five operations are available: cognition, memory, convergent production, divergent production, and evaluation. The six categories of output include: units, classes, relations, systems, transformations, and implications. These categories are defined in Appendix A. Each combination of one content, one operation, and one product represents one unique class of intellective function. The functions, based as they are on combination of categories within three orthogonal factors, may be represented as a cube composed of 120 cells. Such a cube is shown in Figure 1, with each geometric dimension corresponding to one Guilford dimension. Each cell represents a specific intellective function such as "cognition of figural units," denoted by an "x" in Figure 1, or "memory" of symbolic classes, "evaluation of semantic relations," etc.

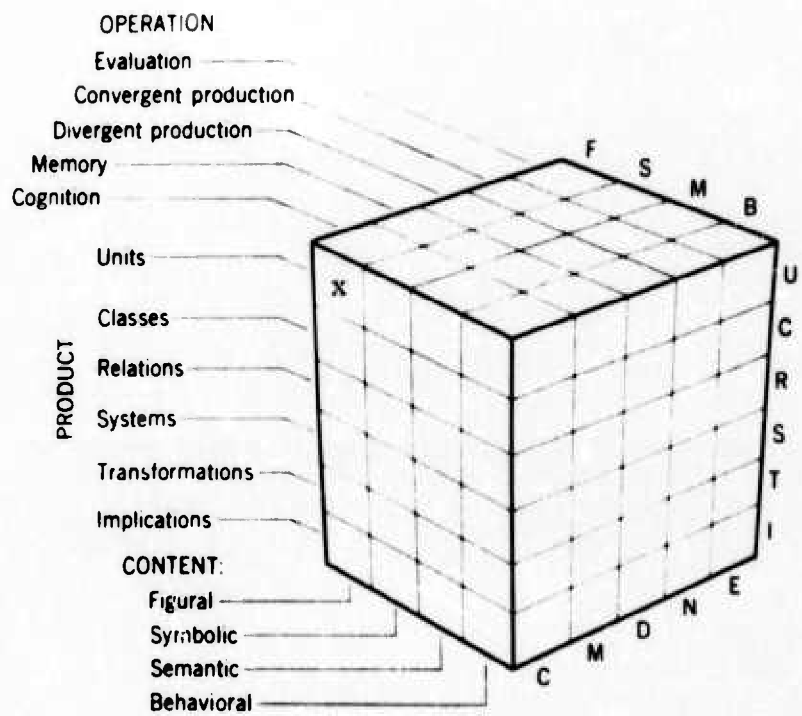


Figure 1. Guilford's Structure-of-Intellect model.

Guilford and his colleagues have identified examples of performance and tests for each of a majority of the available cells. Their work has thus provided an appropriate framework for selecting a set of mental tasks of importance during the operation of any system and for determining those synthetic tasks which may be conveniently administered to experimental subjects. These synthetic tasks address the same intellective functions as the tasks of direct interest.

Previous to the effort which provides the subject of the present report, Siegel and Cosentino (1971) constructed a set of items which will be employed as a basis for measuring the intellective load carrying capability of experimental subjects in the current program. Fifty-three professionals widely drawn from the aerospace industry were asked to provide magnitude estimates of importance to the tasks of an astronaut of each of the categories within the three Guilford dimensions. Three categories of content (figural, symbolic, and semantic), four categories of operation (cognition, memory, convergent production, and evaluation), and three categories of product (relations, systems, and implications) were found to be significantly more important to these tasks than were the remainder of the categories. From this set of categories, twelve specific intellective processes were then isolated by combining each of the four operations with each of the three content and product pairs.

It was found that tests applicable to two of the processes thus determined, convergent production of figural systems and evaluation of figural systems, were not available or were poorly defined. Hence, the list of twelve categories was modified to the following:

Cognition of Figural Systems
Cognition of Semantic Implications
Cognition of Symbolic Relations

Memory of Figural Systems
Memory of Semantic Implications
Memory of Symbolic Relations

Convergent Production of Semantic Implications
Convergent Production of Symbolic Relations
Convergent Production of Semantic Relations

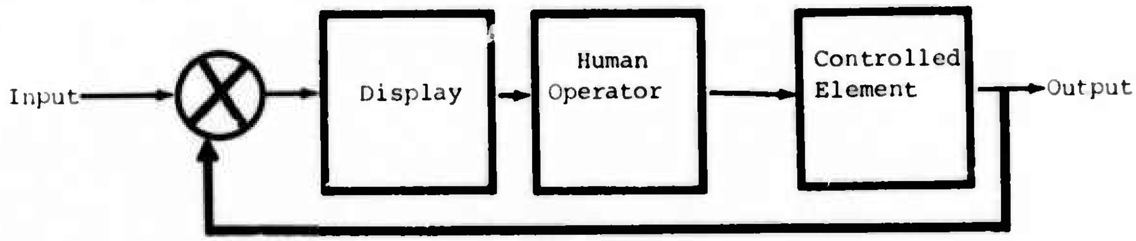
Evaluation of Semantic Implications
Evaluation of Symbolic Relations
Evaluation of Symbolic Systems

Items were then written which addressed each of the twelve listed mental functions. The difficulty of each item was evaluated by a group of graduate students in psychology. Item revisions were performed as needed to produce twelve final sets of thirty test items for the Guilford functions most relevant to man/machine systems. Within each set of 30,

the items are scaled along an equal interval scale of difficulty. These items, presented aurally, will provide the basis for the intellective task performed by each subject during the intellective load threshold establishment work.

Perceptual-Motor Load

The perceptual-motor task to be presented to the experimental subject will be tracking a target on a small cathode ray tube display screen. The diagram below shows a generalized tracking situation.



In a system of this type the actual input displacements are not displayed to the operator. Only the error, the difference between input and output, is displayed. This presentation is analogous to many actual aerospace situations, such as maintenance of a proper path along a glide slope or maintenance of a fixed heading or altitude.

It is generally agreed that the predominant response of a human who controls a system such as this is linear, plus a varying amount of spurious noise. The tracking system is then a typical closed-loop linear system. It contains a load, or controlled element, a human controller, and a linear relationship between input and output.. It is the linear aspect of the controller's behavior which is of interest here.

Operator behavior may be analyzed in a system such as this through the "frequency response" method of the control engineer. This approach will provide several components of human transfer function: response amplitude ratio for each input frequency, and phase shift for each input frequency.

The essential feature of the frequency response method is mathematical description of the system elements in terms of response to input signal frequency. If an input wave, $B \cos \omega t$, with frequency ω radians per second is presented, the operator's output sine wave may be represented as a function of time t by $C \cos (\omega t + \phi)$. This output lags behind the input by an angle ϕ, and the amplitude ratio A (output/input) equals C/B. The values of A and Φ may be calculated with respect to time t from the input signal $\sin \omega t$ or $\cos \omega t$ and the control element movements $(c(t))$ during the time interval from 0 to T through the following equations:

$$A \cos\phi = \frac{1}{T} \int_0^T c(t) \sin \omega t \, dt$$

$$A \sin\phi = \frac{1}{T} \int_0^T c(t) \cos \omega t \, dt$$

The following equations serve to separate A and ϕ:

$$A = \sqrt{(A \cos \phi)^2 + (A \sin \phi)^2}$$

$$\phi = \arctan(A \sin\phi / A \cos\phi). *$$

Amplitude ratios and phase lags representing the system at various frequencies may be displayed separately on a Bode plot, such as that of Figure 2. Such a plot forms a complete description of a linear element.

An operator may be expected to track an input signal with considerable accuracy up to some particular frequency which is unique to that operator. Above that input frequency, the operator is not able to "keep up" with the input signal and his amplitude ratio will drop further and further from unity as input frequency is raised to higher and higher levels. It is also expected that the operator's phase lag will increase with higher input frequency.

Within the current work, we anticipate that deterioration of amplitude ratio and phase lag will occur when intellective load reaches a given difficulty level, as defined by the underlying Thurstone scale for the intellective items. That point will be taken as the "threshold" of an operator for performing the intellective function required by an individual set of test items.

*These formulae are based on the fundamental trigonometric identities $\sin^2\alpha + \cos^2\alpha=1$ and $\tan\alpha= \sin \alpha/\cos \alpha$.

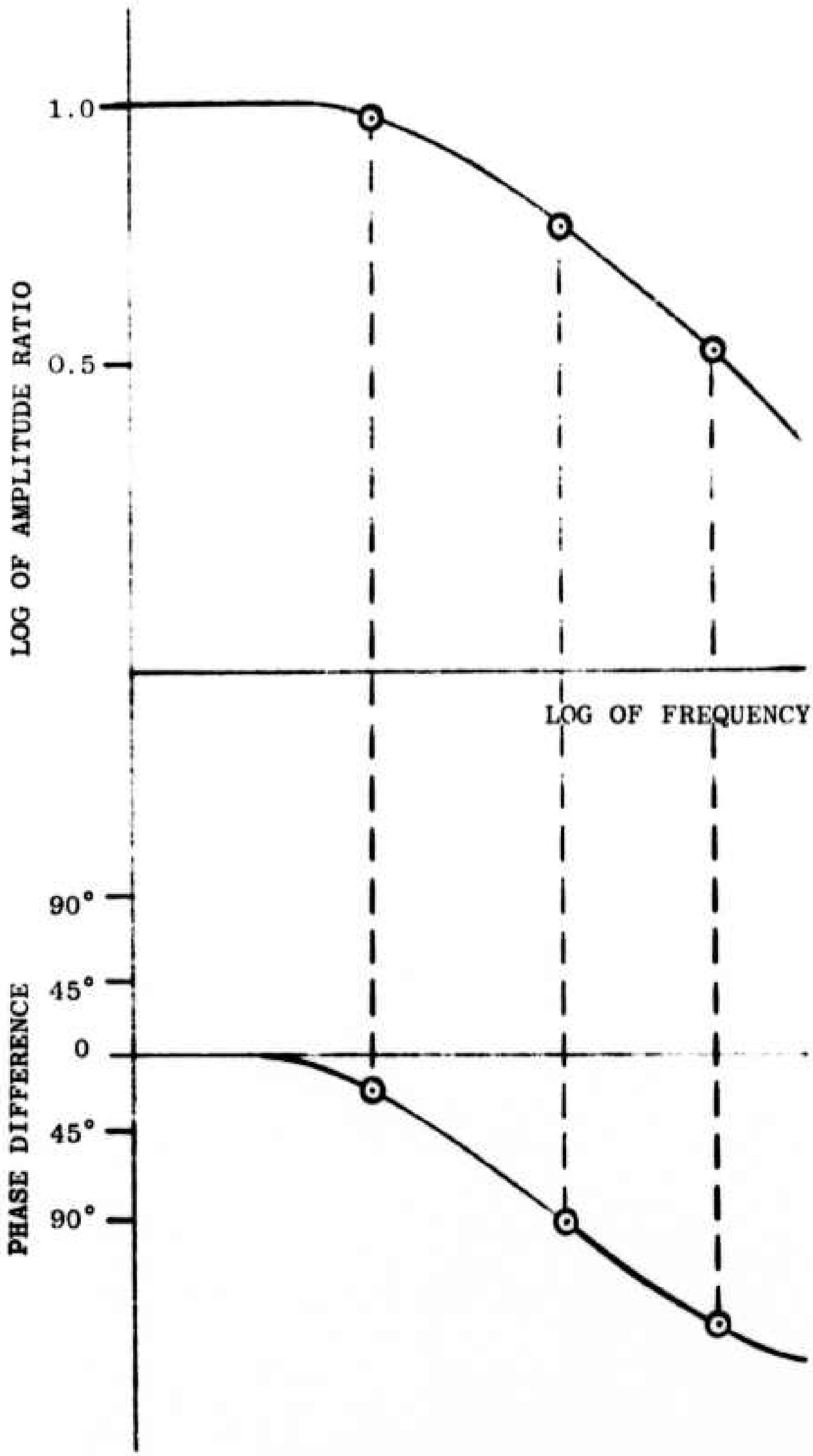


Figure 2. Typical bode plot of human tracking performance, showing amplitude ratio and phase difference at three frequencies.

CHAPTER II

APPARATUS DESIGN

This section presents an overview of the design of the equipment system under construction. The system will allow combined administration of the intellective and perceptual-motor tasks described earlier. It will automatically record each subject's response to the items testing intellective performance as well as data relating to tracking performance. The system has been designated the APS for Automatic Psychodynamic System in reference to the continuous cognitive and perceptual-motor functions which will be presented and recorded.

Electrical Design

Figure 3 presents a block diagram of the system. The heart of the system is the SPC-12 computer which establishes a target track, stores response information, and computes the data necessary for plotting the transfer function.

Programs for control of the apparatus and for manipulation of data are entered into the computer through the paper tape reader option of the ASR-33 Teletype unit.

The device drive adapter contains interface drivers and receivers for connecting the analog input/output unit to the computer.

Amplitude and position information for the display trace comes from the computer as digital information. The digital information is converted to analog information by the Analog/Input/Output unit. The resulting analog amplitude and position information is stored in the output holding amplifiers.

A response to the trace information displayed on the oscilloscope is made by the test subject through movement at the joystick control. The response is in the form of analog amplitude and position voltages. The analog information is converted to digital information in the Analog Input/Output unit. The digital information is sent to the computer for processing, and the analog track response information is retained in the Output Holding Amplifiers.

The Oscilloscope Display Controller receives and multiplexes the analog data, time sequences the deflection amplifiers, and generates display patterns.

The display device is an x/y oscilloscope with a z blanking feature. Software controlled trace information is displayed as a moving dot on the tube face. The tracking cursor (subject's response cursor) is displayed as a .5 centimeter diameter circle.

Specific design features of the APS are presented by Siegel and Cosentino (1971) with certain exceptions which will be detailed. The status of software development and of hardware procurement and development is discussed on the following pages.

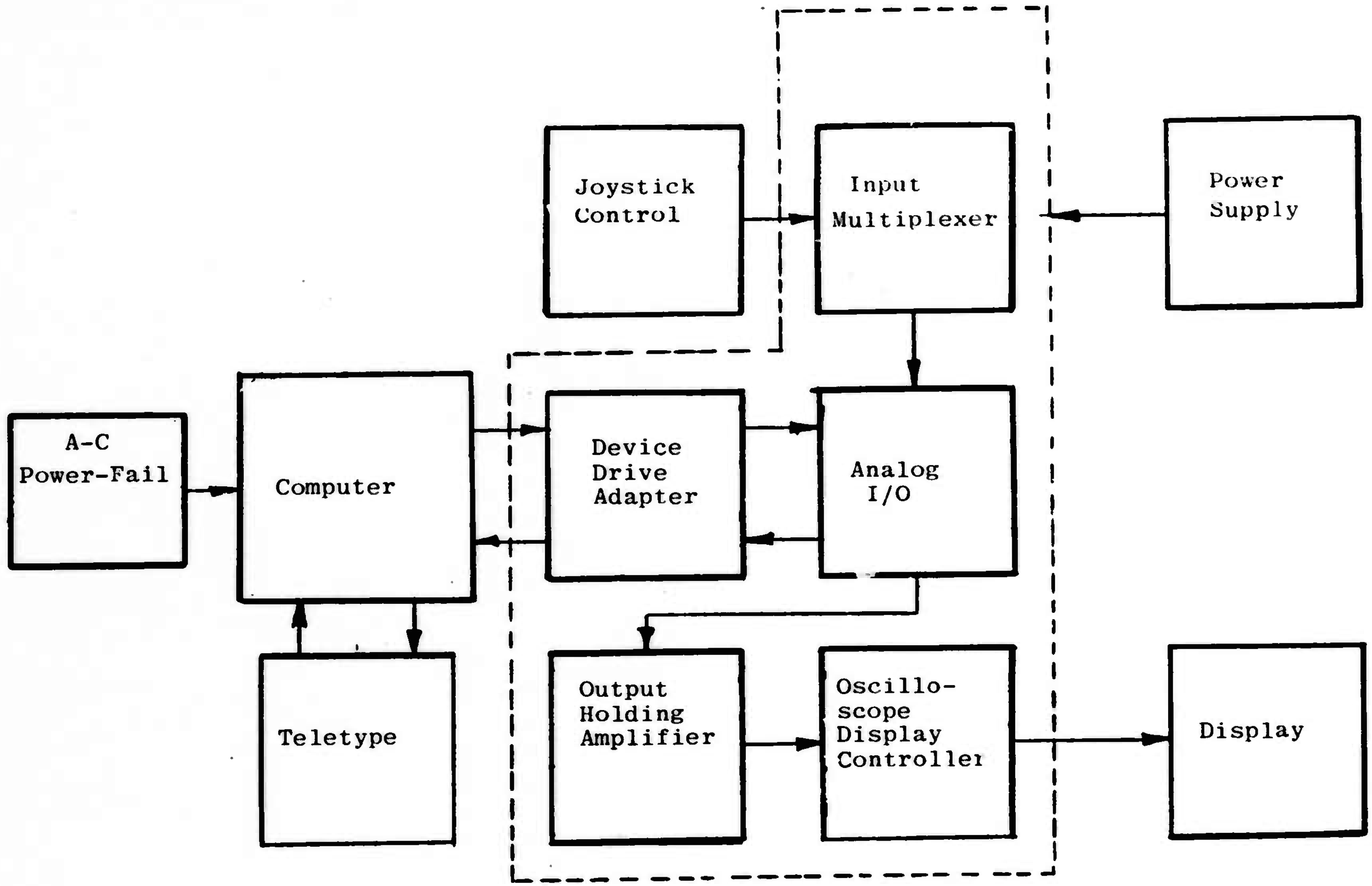


Figure 3. System block diagram.

Software

Experimental subjects are to track, by manipulation of a stick control, an input signal whose motions are controlled in each dimension of the display screen by a function equal to the sum of three asynchronous sine waves, thus producing a random appearing signal. At the completion of the aural presentation of an intellective function test item, response timing and integration of tracking error in the horizontal dimension begin. Timing and integration terminate when the subject presses one of four response keys, indicating selection of one of four possible intellective item response choices. The test item number, integrated error, and answer selection are recorded on the teletypewriter. Presentation of the input signal continues without interruption, although response timing and error integration are suspended until the tape recorded presentation of the succeeding test item is completed. This sequence is shown in flowchart form in Figure 4 and is described in greater detail below.

The APS program is being written in an assembler-type language, as required by the SPC-12 minicomputer. Programming of the software routines here described has commenced.

"Load Data" Block

The amplitude, frequency, and phase angle values for each of three sine waves in the horizontal dimension and three sine waves in the vertical dimension are stored in memory.

"Compute Input" Block

Components of the input to the display of the form $I = X \sin(y\omega + z)$ are computed. Sine values are determined by searching a stored table of the sines of angles 0 through $\pi/2$. One hundred values of the sine are tabulated. They are equally spaced through the range of sine values (not range of angles).

Since the display screen is 8 by 10 cm, full deflection of the input signal from the screen center would be a distance of 4 cm. Allowing 100 sine values, then the largest difference between the positions of points representing adjacent sine values would by 4/100 or a distance of .04 cm. in the worst case. This distance is not resolvable by an operator and may, in fact, be considerably finer than required.

The $y\omega$ term of each component is incremented as appropriate with each iteration, and is reduced by 2π whenever it exceeds the value of 2π.

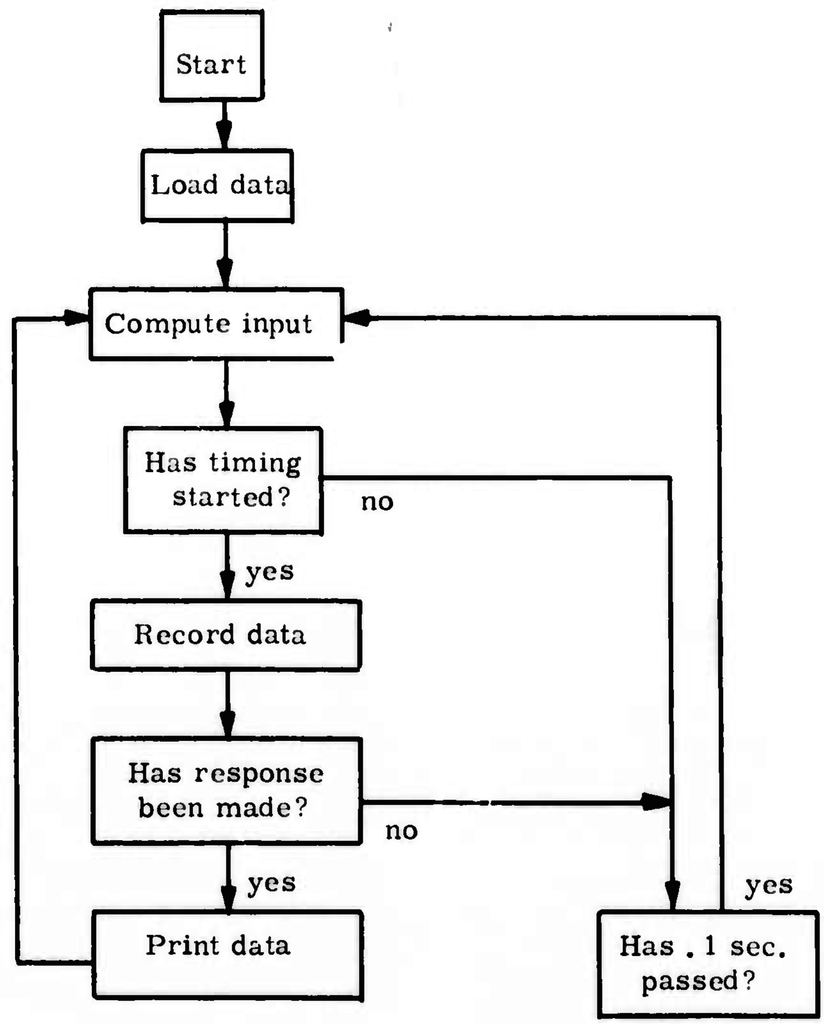


Figure 4. Flowchart of APS program.

The vertical and horizontal components are similarly computed and stored. The input value of each dimension is subtracted from the corresponding joystick voltage, and these differences are sent to the holding amplifiers for display.

"Has Timing Started?" Block

If the subject response timing has not been initiated by a tone (subliminal to the subject) on the aural tape, the program waits until the termination of the current .1 second time frame, then recomputes the input signal. If response timing has been initiated, tracking error recording and response timing are undertaken.

"Record Data" Block

Tracking error is only measured in the horizontal dimension. This value is simply the display deflection voltage in the horizontal dimension.

Two measures, $A \cos\phi$ and $A \sin\phi$ are calculated at each interval as:

$$A \cos\phi = (\text{control position})(\sin\phi)(\text{time})$$

$$A \sin\phi = (\text{control position})(\cos\phi)(\text{time})$$

These are calculated for each of the three components and summed across iterations. Response time is measured by incrementing a counter by 1 each time control passes through this routine. The counter then holds the time (in tenths of a second) that has elapsed since the initiation of response timing.

"Has Response Been Made?" Block

If a subject response key has not been depressed, the program waits until the end of that .1 second time frame, then returns to the input signal generation routine.

If a subject response key has been depressed, an interrupt servicing routine is entered. This interrupt servicing routine simply passes control to the output routine.

"Print Data" Block

The number of current question, the particular response made, response latency to intellective question , integrated error in the X dimension for each of the three component waves, and response time are printed out at the teletype. Control then passes

to the input generation routines. Tracking error will not be recorded until the next "start" pulse is provided by the tape recorder.

$A \cos\phi$ and $A \sin\phi$ will be used to compute phase shift (equal to $A \sin\phi/A \cos\phi$) and attenuation (equal to $\sqrt{(A \cos\phi)^2 + (A \sin\phi)^2}$) manually.

Subject Console

A perspective drawing of the console at which subjects will be seated is shown in Figure 5. The tracking display is presented on the 8 x 10 cm. cathode ray tube which is directly in front of the subject and approximately at his eye level. The "joy stick" tracking control (not shown) will be mounted in the center of the desk surface, and the four response keys (not shown) will be mounted in a chassis which will be positionable, according to the preference of the individual subject, on either side of the desk surface.

Hardware

The status with regard to design and construction of each hardware aspect of the APS system is discussed below.

Computer

The General Automation SPC-12 minicomputer was selected for use in the APS system. An SPC-12, in good condition, was purchased from a local corporation. This machine was returned to General Automation, Inc. where it was thoroughly rehabilitated and made compatible with the various peripherals required by the APS. Various assemblies were updated so that the machine is now functionally identical to the model of SPC-12 currently being produced. This machine now carries a warranty identical to that of a new machine, and it is guaranteed by General Automation, Inc., to interact properly with current available models of peripheral units to be used within the APS. The total cost of this particular SPC-12 minicomputer was considerably less than that of the purchase of a new SPC-12. This saving has partially served to offset unanticipated and considerable increases in the cost of peripherals, the display unit, control stick, and other required items.

Display Unit and Control Stick

The principal system elements with which experimental subjects will directly interact are the cathode ray tube display unit and the stick which controls the tracking cursor. Units produced by Tektronix, Inc. have been selected for these applications. A Tektronix Model 602 display unit and a Tektronix controller Model 015-0175-00 have been obtained.

The display has been calibrated and attenuating resistors have been installed in the vertical and horizontal amplifiers. The attenuation is 10:1. Full scale deflection is 4 cm. for both +5.12 volts and -5.12 volts input signals on both horizontal and vertical coordinates. The deflection factor is .128 volts/cm.

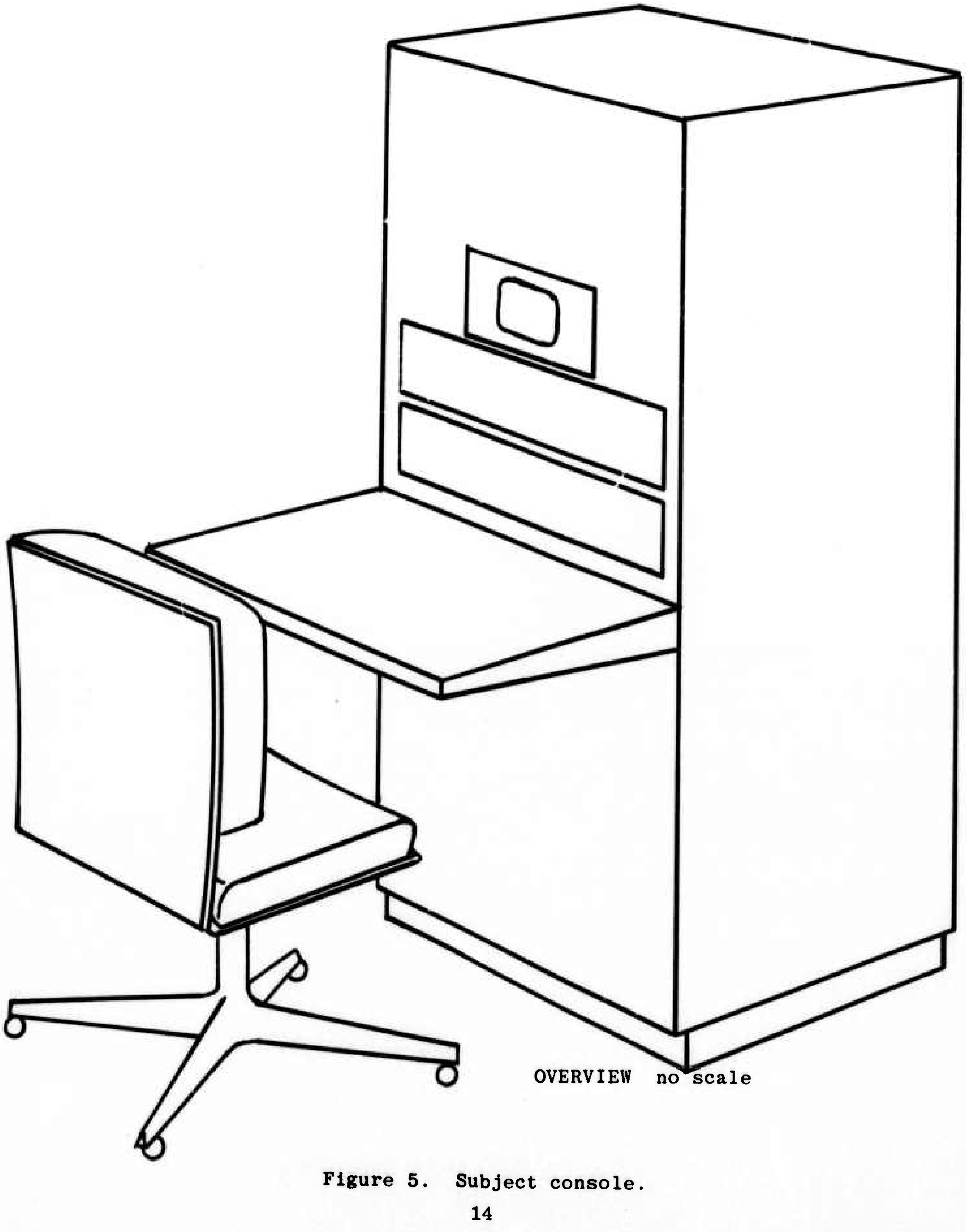


Figure 5. Subject console.

Peripheral Equipment

A variety of peripheral equipments are required for interfacing with the SPC-12 minicomputer, the display unit and control stick, and input-output functions. The required units have been purchased from the General Automation, Inc. This selection helps to ensure compatability with the selected computer and to gain access to aid in system integration from field engineering personnel of General Automation, Inc.

The units include:

Universal Interface Unit
Peripheral Control Extender Board
System I/O Adapter
ASR 33 Console Teletypewriter
Analog I/O Unit
Hi-Level Differential Input Multiplexer
Analog Output Holding Amplifier

Oscilloscope Display Controller

Circuits for the display portion of the oscilloscope display controller (ODC) card have been designed, breadboarded, and tested. Parts have been received for the display controls.

The circuits for chopping and blanking the display are shown on the ODC schematic presented as Figure 6. The chop output is a timing pulse that alternately samples the trace and track inputs at periods of 64 microseconds. An eight microsecond blank pulse conditions the z amplifier to eliminate an erroneous display during the transition of trace and track to trace display inputs. The oscillator is crystal controlled and the logic circuits are TTL.

Figure 7 shows the circuits used to generate the track display. Signals, designated VTKI and HTKI, come from the holding amplifiers in the computer I/O unit. The inputs are in the range of +5.12 volts to -5.12 volts. Both VTKI and HTKI input are fed to a voltage follower. The DAC input is a 60 cycle sine wave which is attenuated, phase shifted 90° and fed to a voltage follower in the vertical channel. The DAC input is also attenuated and fed to a voltage follower in the vertical channel. The outputs of the voltage followers in the vertical and horizontal channels are then fed to a differential amplifier . A voltage gain of 1.0 is maintained through the entire circuit so that the resultant voltage,VERTTK, is the input voltage VTKI which rides on top of a sine wave that is .5 volts peak to peak. Since the a.c. input on the vertical channel is phase shifted 90° from the input on the horizontal channel, the display will be a circle position dependent on inputs VTKI and HTKI. Figure 8 presents the circuits used to switch from track display to trace display. The circuit used for the switching is an analog switch controlled by the chop output from the timing circuits. The trace inputs VTR and HTR came from the holding amplifiers in the computer I/O unit. Since the analog switch is followed by a voltage follower, no noticable attenuation in input signal is obtained when pressing through the analog switch and the output signals VERTDI and HORDI are the same amplitude as the input signals. Signals VERTDI and HORDI are inputs to the oscilloscope display.

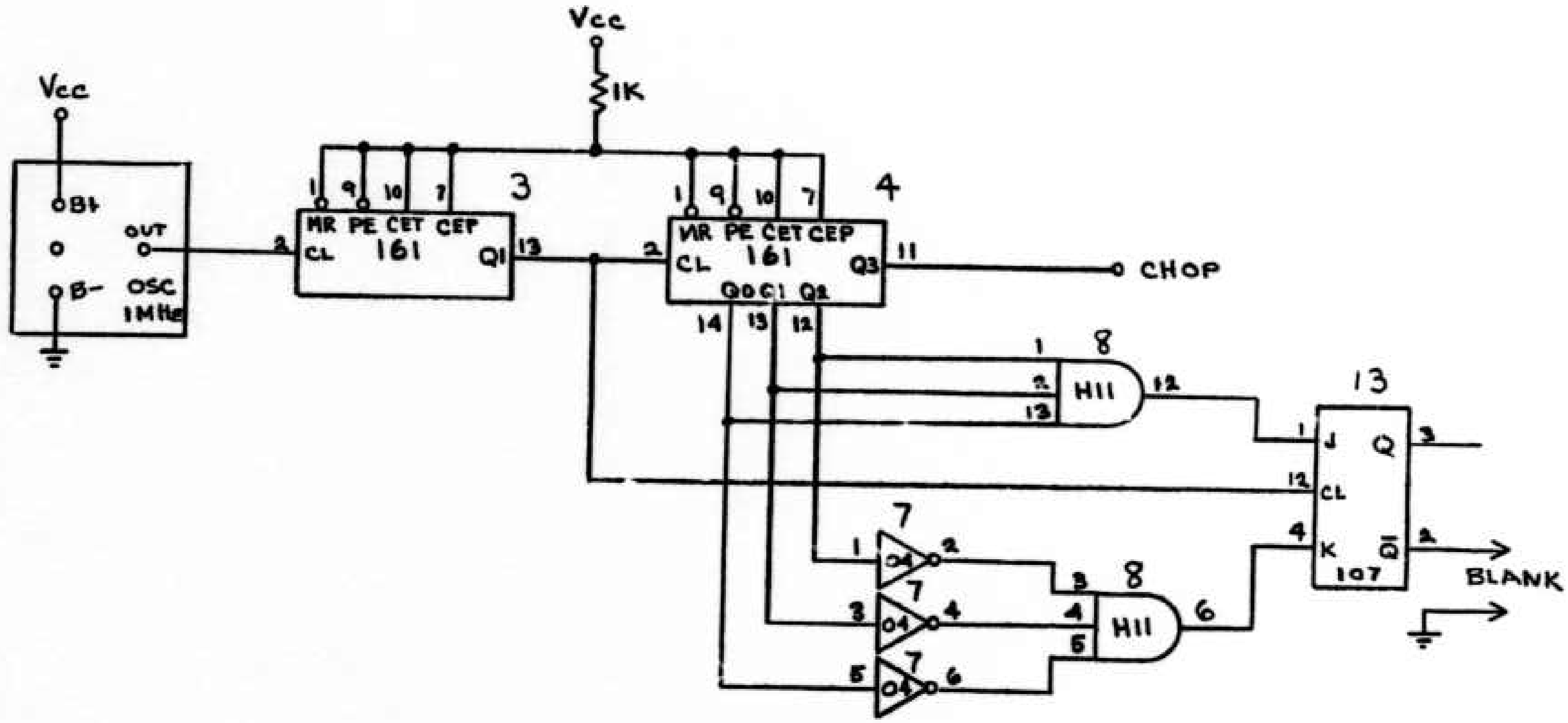


Figure 6. Schematic of oscilloscope display controller 1.

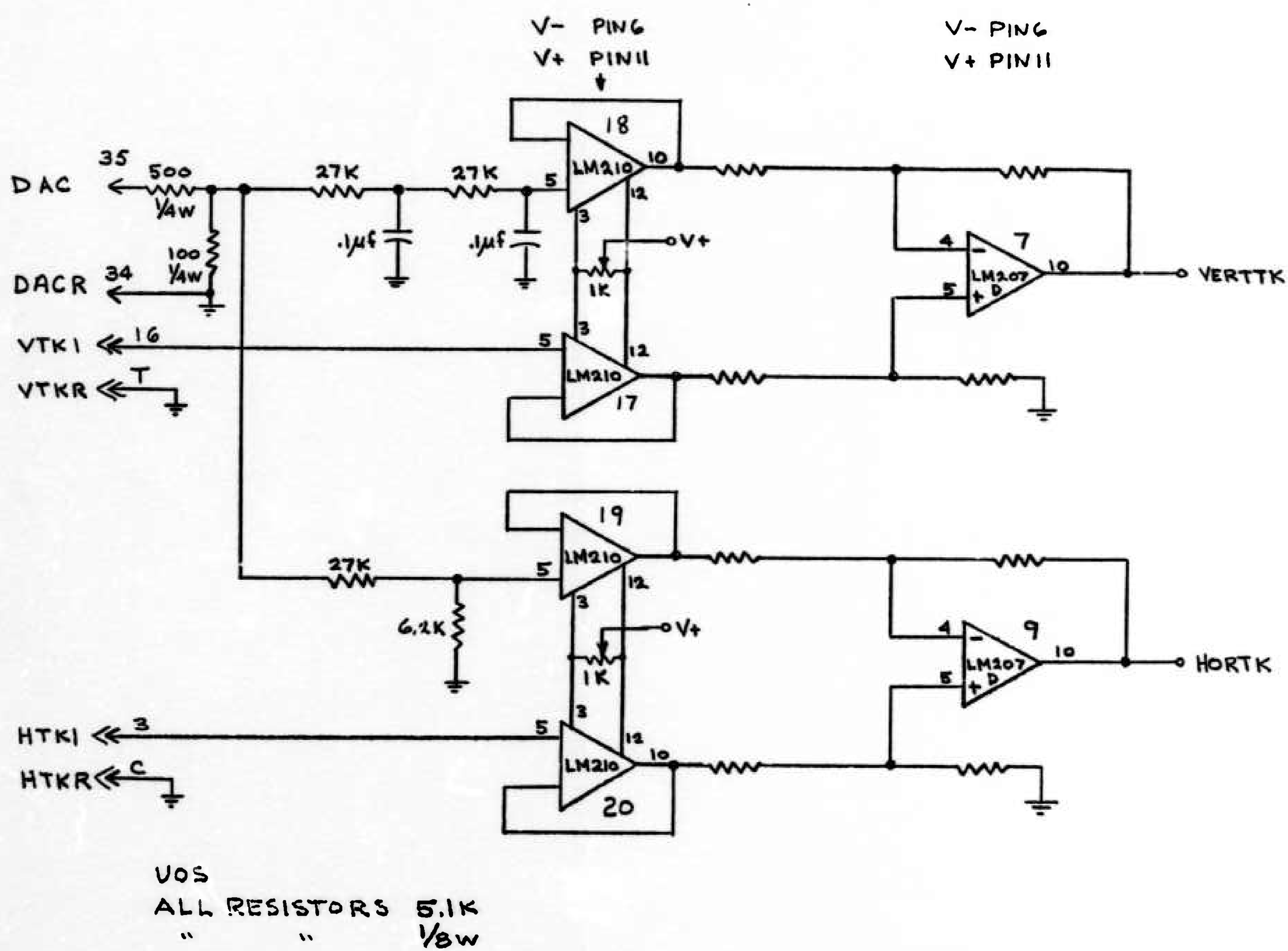


Figure 7. Schematic of oscilloscope.

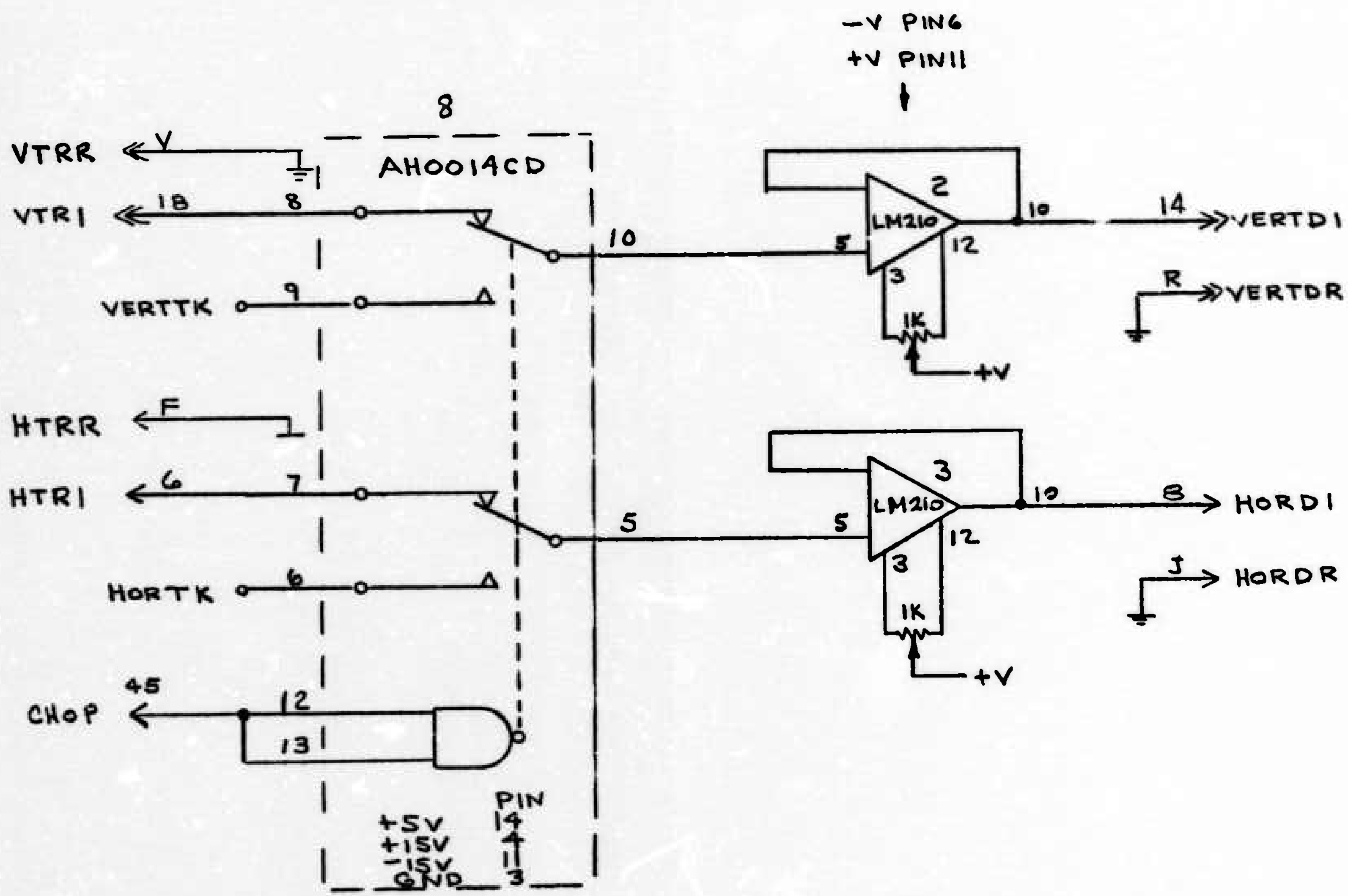


Figure 8. Schematic of oscilloscope display controller.

Cassette Tape Circuits

A 1KC oscillator was breadboarded and used to generate a tone on magnetic tape for timing purposes. An active filter circuit has been breadboarded to seperate the 1KC burst from normal voice frequencies. If this circuit proves feasible, a single track tape recorder will be used in place of a dual track recorder.

Mechanical

The subject's console cabinet (as shown in Figure 5) complete with desk surface and exterior panels, has been obtained. Internal structure to support the SPC-12 minicomputer, I/O units, and power supplies is under construction.

Summary of Progress

Detailed design of the APS and breadboarding of new circuits, when considered necessary, have been completed. Actual contruction of the system, delayed considerably by delays in the receipt of electronic components, is about 40 percent complete. However, almost all required parts and components have now been received and construction rate has accelerated.

The following decisions which impact on the research conduct, have been made. Tracking error will be sampled 10 times per second. This sampling rate is an acceptable compromise between the desire to achieve a maximally detailed recording of performance and the time required for completion of the necessary computer processing per sampling interval. Amplitude ratio and phase shift related to the three sine wave components acting on only horizontal movement of the target will be recorded. This decision was made to allow maximum detail in one axis as opposed to less detail for two axes. These data are held fully adequate for describing the characteristics of a linear control system, and allow the required data processing within each sampling interval.

Software has been developed in detailed flowchart form with attention given to the special capabilities available within the SPC-12 programming language. Coding of this software has begun.

REFERENCES

Guilford, J.P., Comrey, A.L., Green, R.F. & Christensen, P.R. *A factor analytic study of reasoning abilities I. Hypotheses and description of tests.* Los Angeles: University of Southern California, 1950.

Guilford, J.P., Geiger, R.M., & Christensen, P.R. *A factor-analytic study of planning I. Hypotheses and description of tests.* Los Angeles: University of Southern California, 1954.

Guilford, H.P., & Hoepfner, R. *Structure-of-Intellect factors and their tests.* Los Angeles: University of Southern California, 1966.

Guilford, J.P. *The nature of human intelligence.* New York: McGraw-Hill, 1967.

Hoepfner, R., Guilford, J.P., & Merrifield, P.R. *A factor analysis of the symbolic-evaluation abilities.* Los Angeles: University of Southern California, 1964.

Siegel, A.I., & Cosentino, J. *A technique for measuring the intellective load capacity of system operation.* Wayne: Applied Psychological Services, Inc., May, 1971.

APPENDIX A

Definitions of Intellective Categories

INTELLECTUAL CONTENTS (Inputs)

Broad types of information, including both the form in which information is received and the form in which it is processed.

F--Figural. Concrete Items of information. Different senses may be involved, e.g., seeing or hearing. For example, the appearance of a landing site, the shape of a radar return, the texture of a lunar rock.

S--Symbolic. Information items in the form of signs, i.e., any "coded" item. For example, a number indicating a particular status, an equipment designation and number combination, a Morse code element.

M--Semantic. Information in the form of words written or spoken. For example, a radio communication or a computer printout.

B--Behavioral. Information derived from the actions of others, their moods, motivations.

INTELLECTUAL OPERATIONS

The mental activities or processes by means of which raw information is changed into an intellectual product.

C--Cognition. Awareness, immediate discovery or rediscovery, recognition, comprehension, or understanding. For example, an astronaut's becoming aware of an alarm, understanding an an instrument indication, or noticing a malfunction indication.

M--Memory. Retention or storage of information. For example, recall a satellite's last position, remembering standard operating procedures, repeating a message as received.

D--Divergent Production. Generation of information from the given information with the emphasis upon variety or quantity of output. For example, search memory for all possible required docking information, list all possible means of checking the accuracy of decision.

N--Convergent Production. Generation of information from given information with the emphasis on achieving a best or unique solution. For example, choose an alternate docking site, select the appropriate transmission mode, set goals for the work of each operator, solve a plotting problem.

E--Evaluation. Comparison of information with criteria and the decision as to whether the criteria are satisfied using criteria such as identity, similarity, consistency, or satisfaction of class memberships. For example, judge adequacy of information, check different displays of consistency.

INTELLECTUAL PRODUCTS (Outputs)

Forms that information takes as a result of having been processed.

U--Units. "Things," or relatively separate or isolated items, which stand alone. For example, an individual operator, a bright light seen against a dark background.

C--Classes. Schemes for grouping information items according to their similarities and differences. For example differentiating noise pips from signal pips, grouping photographs by content, grouping material collected from lunar surface.

R--Relations. Connections between information items, either as to quantity or as to quality. For example, a brighter light, a louder signal, a trend in successive instrument readings, a greater number of signals.

S--Systems. Schemes for organizing information items according to their interrelationships. For example, a mathematical equation, a pattern of signals, a work schedule, an operational outline.

T--Transformations. Rules for changing the state of information items to another state. For example, decoding messages, changing range estimates from miles to yards, or changing relative bearing to true bearing.

I--Implications. Special kind of relations involving prediction from present or known information to future or unknown information. For example, predicting the position of a lost satellite, anticipating supply needs, filling in missing information.